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Status of Indirect Drive ICF Experiments on the National Ignition Facility

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Disclaimer

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Status of Indirect Drive ICF Experiments on the National Ignition Facility*

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In the quest to demonstrate Inertial Confinement Fusion (ICF) ignition of deuterium-tritium (DT) filled capsules and propagating thermonuclear burn with net energy gain (fusion energy/laser energy >1), recent experiments on the National Ignition Facility (NIF) (Fig.1a) have shown progress towards increasing capsule hot spot temperature (Tion>5 keV) and fusion neutron yield (~10^{16}), while achieving ~2x yield amplification by alpha particle deposition. At the same time a performance cliff was reached, resulting in lower fusion yields than expected as the implosion velocity was increased. Ongoing studies of the hohlraum and capsule physics are attempting to disseminate possible causes for this performance ceiling.

Experiments to understand the effect and mitigate potential sources of fuel preheat while improving the radiation symmetry in hohlraums are ongoing. Recent results show that higher energy preheat x-rays (hν>2 keV) are reduced in alternative hohlraum materials to pure Au such as uranium or by applying mid-Z liners to the inner wall surface. Furthermore, lower densities or near vacuum hohlraum fills have demonstrated a strong reduction in the amount of preheat hot electrons generated by laser-plasma instabilities. These experiments have also shown that the laser energy coupling into x-rays is improved by ~20% by reducing laser backscattering from the target.

High resolution 3D simulations, validated by inflight capsule radiography data, have also shown that the tent holding the capsule and low mode radiation asymmetries have strong negative impacts on implosions by the hydrodynamic instabilities they cause at stagnation (Fig. 1b). The relative importance of these factors depends on the ICF design, i.e. capsule ablator (CH, HDC, Be) and laser pulse (High Foot, Low Foot, adiabat shaped-AS, Fig. 1a). Studies to mitigate low-mode asymmetries and investigate alternatives to the tent mount are ongoing.

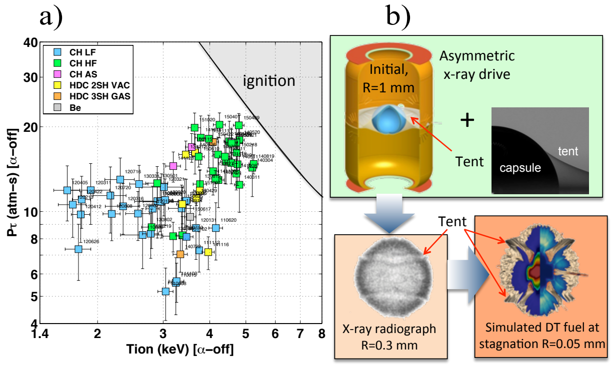

Figure 1. a) Lawson criteria Pτ of NIF DT fuel implosions vs hot spot temperature (Tion) for various ablators (plastic-CH, diamond-HDC and Be) and hohlraum fills (1.6 mg/cc for High Foot-HF and 3-Shock HDC, 0.96 mg/cc for Low Foot-LF and 0.03 mg/cc for near vacuum hohlraums-VAC). b) The tent holding the capsule inside the hohlram and low mode radiation flux asymmetries are potential culprits of performance limits; they are observed at peak implosion velocity (R=0.3 mm capsule radius) and are simulated to have a negative impact on hot spot stagnation (R=0.05 mm).

In upcoming ICF experiments with CH, HDC or Be capsules low mode asymmetries and hydro-instabilities will be mitigated by optimizing the hohlraums and laser pulses to reach nearly 1-D implosions that are well understood. These more robust designs will be then subjected to higher implosion velocities required to approach ignition.

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